The Patent Office
Concept House
Cardiff ~~Road~~
Newport
South Wales
NP10 8QQ

REC'D 27 FEB 2003

PCT

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH
RULE 17.1(a) OR (b)

PCT/GB03/99

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed

Dated 14 February 2003

Patents Form 1/77

Patents Act 1977
(Rule 16)

THE PATENT OFFICE
F
15 JAN 2002
RULE 97
NEWPORT

The Patent Office

16JAN02 E688145-3 D10002
P01/7700 0.00-0200867.0

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1. Your reference	cau.1999.uk.dk.dfe
2. Patent application number *(The Patent Office will fill in this part)*	15 JAN 2002 **0200867.0**
3. Full name, address and postcode of the or of each applicant *(underline all surnames)*	University Court of Glasgow Caledonian University Cowcaddens Road GLASGOW G4 0BA
Patents ADP number *(if you know it)*	8284481001
If the applicant is a corporate body, give the country/state of its incorporation	
4. Title of the invention	Electric motor monitoring system
5. Name of your agent *(if you have one)*	Kennedys
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Floor 5, Queens House 29 St Vincent Place GLASGOW G1 2DT
Patents ADP number *(if you know it)*	8036758002

	Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

	Number of earlier application	Date of filing *(day / month / year)*
7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	b)

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	22
Claim(s)	
Abstract	
Drawing(s)	5 + 5 8m

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application.

Signature Kennedys Date 14/01/02

12. Name and daytime telephone number of person to contact in the United Kingdom — David Fulton Tel: 0141 226 6826

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

Electric Motor Monitoring System

The present invention relates to the field of monitoring devices for electric motors. In particular, it relates to an arcing event detection device that provides a means for monitoring and recording a variety of electric motor diagnostics.

Accurate and reliable diagnostic measurements are of paramount importance in the application and control of DC and AC electric motors. The Prior Art teaches of various methods for measuring speed and torque associated with such motors that require the addition of mechanical or electrical components to the motor drive system.

A summary of conventional speed measurement systems taught in the Prior Art include:

1) Optical techniques whereby reflected light from rotating components is measured. Such systems require a reflective tape to be placed on the motor shaft. However, within industrial situations maintaining the signal integrity due to the detrimental effects of

dirt, loss of connection, shaft vibration etc. becomes highly problematic.

2) Magnetic Pick-up Devices that employ the Hall effect to measure speed. These devices are susceptible to errors due to magnetic field variations and also require careful positioning on the motor.

3) Eddy Current Displacement Probes and Variable Reluctance Sensors that both require to be physically mounted close to irregular rotating components such as flats on the shaft or gear teeth. Like the Magnetic Pick-up Devices these probes and sensors require careful positioning and are susceptible to errors due to magnetic field variations around the electric motor.

4) Hand Held Tachometers that again require physical contact with the rotating shaft of the motor. However, when employed with low power motors the increased torque required during measurement can result in the motor speed being altered.

Similarly, conventional torque measurement systems taught in the Prior Art include:

1) Dynamometers, used to measure torque in rotating machinery. In general these devices are impractical to fit to motors once they have been integrated into a particular application.

2) Measurement of motor current that then allows an estimate of the torque to be calculated by employing motor performance characteristic curves. The major

drawback to this technique is that it can be highly inaccurate due to fluctuations in load and speed of rotation.

3) Measurement of motor back e.m.f. Although the back e.m.f. varies with load it also depends on the motor speed therefore such a method is susceptible to erroneous readings.

All of the above measurement methods are intrusive and require full access to the motor shaft, the power cables, or the load being driven by the motor. Such measurements often involve the removal of safety guards that can have obvious implications to user safety.

In addition, industrial plants may require to be stopped in order to allow installation of these speed and torque measurement devices with the effect of increasing the related maintenance costs. Many of these industrial plants employ large numbers of electric motors that require to be monitored. Therefore, it is often impractical to install speed and torque monitoring equipment on all the individual electric motors.

US Patent No. US 4,577,151 in the name Tanisaka et al. attempts to address some of the problematic features of the Prior Art as highlighted above. This document teaches of a spark monitor device, comprising of an antenna, which is suitable for receiving high frequency noise. The antenna then detects the high frequency noise associated with the sparks generated in a current collector of a rotary electric motor. Monitoring of the electric motor is then achieved by analysing the state of

the spark generation on the basis of the product of a peak value of the high frequency noise exceeding a set predetermined value and a time interval during which the peak value exceeds the set predetermined value. This product value is calculated for every arcing event within the motor such that alarm signals are activated in response to each individual arcing event.

Figure 1 presents a simple two pole DC electric motor 1, that can be tested employing the spark monitor device of Tanisaka et al. The two pole DC electric motor 1 is shown in three different states of operation. From Figures 1(a), (b) and (c) it can be seen that the two pole DC electric motor 1 further comprises a motor field coil 2, two motor brushes 3, four armature coils 4 and a four sector commutator 5.

Figure 1(d) and (e) show the conditions of the current in one of the armature coils 4 as the commutator 5 passes under a brush 3 from which a constant current I amps flows. The current flowing through the armature coil 4 prior to commutation is +I/2 amps (corresponding to Figure 1(a)). During commutation the current in the coil 4 is effectively reversed to −I/2 amps (corresponding to Figure 1(c)). This process of current reversal takes time T_c seconds. If the current is fully reversed in time T_c then there will be no arcing at the brush contact 3 and the current versus time profile shall be as shown in Figure 1(d).

However, if the current is not fully reversed during time T_c the commutation time is extended by arcing at the trailing edge of the brush 3, as represented in Figure

1(e). This process is known in the art as under commutation. Arcing may also occur if the current reversal is too fast resulting in over-commutation producing arcs at the leading edge of the brush 3.

The following are a list of factors known to affect or influence the arcing characteristics of the electric motor, namely:

1) Inherent properties of the brushes. Different brush materials exhibit differing conduction properties and so affect the occurrence of arcing events. Fragmentation of the brush material results in electrical field stress enhancement points that again affect the likelihood of arcing. Sharper edges and greater brush dimensions both increase the chances of such fragmentation. In addition, the inherent shape of the brushes also influences arcing. Sharper edges result in increased current densities and thus an increased probability of the formation of an arc;

2) The work factor between the brush and the commutator materials also affects the strength of the electric field required to produce arcing. Ionisation voltages, hence arc formation, is found to be material dependent;

3) Mechanical vibrations within the electric motor affect the charge transfer and the production of fragments from the brush and commutator. Thus mechanical vibrations within the electric motor

directly affects the formation of the arcing event;

4) Inter segment capacitance and inductance affects the flow of charge from the directly connected and non-directly connected segments of the commutator. This factor affects the build up or dissipation of charge within the electric motor thus affecting the possibility of arcing occurring;

5) The purity and type of gas in the region of the brushes affects the ionisation potential and hence the influence of the arcs produced. In addition any gaseous discharge affects the composition of the gas in the region of the arc, producing charged and excited species that also affects the suppression or regeneration of discharge events;

6) Aerodynamic effects, such as turbulence around the brush contact area also acts to alter the gas density and hence the affects of the arc discharge;

7) Metallic components that become etched and fragments that evolve within the motor act to produce field stress enhancement points that also affect the arcing characteristics;

8) Commutating coil e.m.f. The time T_c during which a coil is short circuited is typically 2ms or less. The rate of current change is therefore very large, typically 100,000 Amps/second. Each armature coil will have an appreciable inductance,

and hence during commutation an inductive e.m.f. is generated that acts to oppose the current reversal. This induced e.m.f increases the probability of arcing. Although interpoles or compoles can be employed to reduce the inductive e.m.f. they only act to reduce arcing when the motor is running in the steady state. It is found that motor transients still act to produce significant arcing events.

Each of the factors outlined above affects the ability of an arc to form, the duration of the arc and the arc intensity. In general these arcing events are rather random in nature, the time duration typically varying between a few microseconds to several milliseconds. The arc is therefore essentially an impulse function with an associated broad band of frequencies in the range 0Hz to 1GHz.

It is these associated frequencies that result in television, radio and general communication interference. Such interference is generally unwanted and the Prior Art teaches of equipment designed at great expense to reduce such arcing events, usually with only limited success. Unlike the teachings of the Prior Art the present invention attempts to utilise these previously undesirable signals in order to provide a means for measuring a range of DC and AC electric motor/machine diagnostics including motor speed and torque.

The teachings of Tanisaka et al. exhibit certain inherent theoretical and practical problematic features. Most importantly the teachings are limited to the counting of

the occurrence of sparking events. The described apparatus does not offer any facilities for relating an arcing event to a particular mechanical or electrical component within the electric motor. Similarly, there is no facility for physically locating the individual arcing events thus, information regarding the deterioration or alignment faults of the component parts of the electric motor cannot be extracted.

In addition, it can be shown that the relationship between the amplitude of a spark and the applied torque is non linear. The width of the spark can also be shown to be directly proportional to the applied force. Therefore the system as taught by Tanisaka et al. will only work where the electric motor is operating under a constant load. Fluctuations in the load would lead to false alarm signals being generated.

A third major drawback of the teachings of Tanisaka et al is the fact that in industrial environments, there can be significant levels of background electrical noise generated from a variety of sources e.g. during the opening and closing of relays and electric contacts. Tanisaka's et al method has no way of discriminating between arcing within motors and external noise. Therefore, the presence of such external noise will again result in false alarms.

The teachings of Tanisaka et al indicate that the sparking on current collectors is an irregular low frequency event. Therefore, their device is limited to use with generators where arcing only occasionally occurs. However, as outlined in detail above, it is now

known in the Art that arcing is always present in mechanically commutated machines and so arcing signals are frequently produced as the electric motor operates.

It is an object of the present invention to provide an electric motor monitoring system for the detection of high frequency arcing events that provides a facility for locating and identifying electrical and mechanical faults within the electric motor.

It is a further object of the present invention to provide an electric motor monitoring system for the detection of high frequency arcing events that provides a facility for optimising the alignment and monitoring the efficiency of the electrical and mechanical components of the electric motor.

A yet further object of the present invention is to provide an electric monitoring system for the detection of high frequency arcing events that is capable of suppressing background electrical noise so improving the signal to noise ratio of the detected signals.

According to a first aspect of the present invention there is provided an electric motor monitoring system comprising an antenna, a data sampling means and a data processing means wherein the electric motor monitoring system provides a diagnostic for monitoring both mechanical and electrical components of the electric motor.

Most preferably the antenna provides a means for detecting high frequency signals generated by arcing events within the electric motor.

Preferably the antenna comprises a means for screening background noise so improving the overall signal to noise ratio of the electric motor monitoring system.

Preferably the antenna further comprises a frequency matching unit, wherein the frequency matching unit allows the antenna to be frequency tuned so as to optimise its operation with the electric motor.

Optionally the antenna comprises a balanced Faraday screened loop antenna. Alternatively the antenna comprises an unbalanced Faraday screened loop antenna

Preferably the data sampling means comprises an anti aliasing filter, an analogue to digital converter and a high speed PCI card wherein the data sampling means allows the high frequency signal, over a predetermined length of time, to be captured.

Preferably the data processing means comprises a computer processor capable of manipulating and storing the sampled data.

According to a second aspect of the present invention there is provided an antenna for measuring high frequency signals associated with arcing events in an electric motor, comprising a loop and a loop screen, wherein the loop screen shields the loop from background noise thus

improving the signal to noise ratio of the signal detected by the antenna.

Most preferably the loop screen physically covers all but a small detection section of the loop.

Preferably the antenna further comprises a frequency matching unit, wherein the frequency matching unit allows the antenna to be frequency tuned so as to optimise its operation with the electric motor.

Preferably the loop comprises a conductor and a screened coaxial cable wherein the conductor is turned back on itself so as to form one or more turns, the end of the conductor cable being attached to the screen of the coaxial cable.

According to a third aspect of the present invention there is provided a diagnostic method for monitoring both mechanical and electrical components associated with an electric motor comprising:

1) Detection of high frequency signals associated with arcing events within the electric motor;
2) Sampling the high frequency signal over a predetermined length of time;
3) Processing the sampled data so as to provide information regarding the mechanical and electrical components of the electric motor.

Preferably the diagnostic method provides a means for associating the frequency of the high frequency signal to individual components of the electric motor.

Most preferably the detection of the high frequency signals employs a non-intrusive antenna.

Preferably the sampling provides a means for monitoring frequency modulation and amplitude modulation within the high frequency signals.

Preferably the processing of the sampled data comprises Fast Fourier Transformations of the sampled data so as to convert the sampled data to interpretable frequency spectra.

Most preferably the interpretable frequency spectra comprise frequency features that can be directly associated with particular mechanical or electrical components of the electric motor.

Alternatively the processing of the sampled data comprises calculating an average width of the high frequency signals, above a predetermined level, over a number of arcing events.

Alternatively the processing of the sampled data comprises calculating an average height of the high frequency signals over a number of arcing events.

Alternatively the processing of the sampled data comprises calculating an average ratio of the width and height of the high frequency signals over a number of arcing events.

Optionally the diagnostic method for monitoring both mechanical and electrical components associated with an

electric motor further comprises the step of self calibration of the diagnostic method.

Preferably the self calibration of the diagnostic method comprises a current measuring technique involving the steps of:

1) Measuring the torque on the electric motor by employing the non-intrusive antenna;
2) Measuring directly the current in the electric motor so as to enable the torque on the electric motor to be calculated;
3) Taking the difference between the two methods for obtaining the value of the torque on the electric motor so providing a compensation factor; and
4) Adding the compensation factor to the non-intrusive antenna method for measuring the torque on the electric motor.

Embodiments of the present invention will now be described by way of example only with reference to the accompanying figures, in which:

Figure 1 presents a schematic illustration of a spark monitor device as taught by Tanisaka et al. in conjunction with a two pole DC electric motor;

Figure 2 presents a schematic illustration of an electric motor monitoring system in accordance with the present invention;

Figure 3 presents a schematic illustration of a screened loop antenna employed by the electric motor monitoring system of Figure 2;

Figure 4 presents a measured output signal from the electric motor monitoring system where the system employs:

a) a commercially available antenna;

b) the screened loop antenna of Figure 3.

Figure 5 schematically presents the electric motor monitoring system employed to measure the speed of the electric motor;

Figure 6 schematically presents the electric motor monitoring system employed to estimate the applied load on the electric motor by evaluating:

a) the width of the high frequency arcing events;

b) the Route Means Square (RMS) or other statistical type measurement of the high frequency arcing events;

Figure 7 schematically presents the electric motor monitoring system employed to measure frequency modulations or the arcing events within the electric motor;

Figure 8 schematically presents the electric motor monitoring system employed to measure amplitude modulations of the arcing events within the electric motor;

Figure 9 schematically presents the electric motor monitoring system employed to measure several of the

aforementioned diagnostics of the electric motor simultaneously; and

Figure 10 presents a schematic illustration of a current measurement technique employed to calibrate the electric motor monitoring system.

Figure 2 presents a schematic illustration of an electric motor monitoring system, generally depicted at 6. The electric motor monitoring system 6 employs a computer interfacing and data acquisition method to capture and process arcing events within an electric motor 1. The electric motor monitoring system 6 can be seen to comprise a balanced screened loop antenna 7, an anti aliasing filter 8, an analogue to digital signal converter (ADC) 9, a high speed PCI card 10 and a computer processor 11 for analysing the sampled data. In an alternative embodiment the electric motor monitoring system 6 further comprises an amplifier (not shown). The high speed PCI card 10 is capable of capturing and saving several million points of data to the computer processor 11 for subsequent analysis. The further processing required depends on what particular parameter requires to be measured, as described in further detail below.

Detail of the balanced screened loop antenna 7 is provided in Figure 3. The balanced screened loop antenna 7 comprises a loop section 12 and a frequency matching tuning unit 13. The loop section 12 is constructed from a conductor 14 and a screened coaxial cable 15. The conductor 14 is arranged such that it loops back on itself with the end being attached to the screen of the coaxial cable 15 at the start of the loop section 12.

The screen of the coaxial cable 15 is deployed such that it extends in two directions from the start of the loop section 12 with a small gap being left at the far end.

Employing the frequency matching tuning unit 13 allows the electric motor monitoring system 6 to be optimised for use with a particular electric motor 1 or to be altered for frequency selectivity for use with multiple electric motors. Optimising the frequency selection of the balanced screened loop antenna 7 for a particular electric motor design and geometry has the advantage of optimising the arcing event signal characteristics for the particular fault conditions as outlined below.

In an alternative embodiment it is possible to employ an unbalanced screened loop antenna or a multi-turn screened loop antenna (not shown). The multi-turn screened loop antenna comprises a number of screen coiled loops with a small gap in the cable screen being at the furthest point of the coiled loops.

Figure 4 highlights the significant advantage of employing the balanced screened loop antenna 7 over those previously described in the Prior Art. Antennas employed in the Prior Art are designed to receive continuous broadcast signals. Therefore, employing such an antenna with the present system provides a measured RF signal that is a combination of both the desired electric motor signal and any unwanted broadcast signal as shown in Figure 4(a).

A further problem of employing the antennas taught in the Prior Art for such a measurement is their susceptibility

to ringing when an RF impulse is received. The antenna inductance, stray capacitance and the associated receiver input impedance circuitry create a tuned circuit that can cause prolonged ringing. The duration of the prolonged ringing becomes problematic if the antenna is used to measure the speed of an electric motor (as described below). Ideally it desired that antenna signal oscillations should be completely damped before the next arcing event occurs.

Employing the balanced screened loop antenna 7 significantly reduces these problematic features. As seen in Figure 4(b), the signal to noise ratio of the measured RF signal is greatly improved by employing the balanced screened loop antenna 7. Here the arcing events 16, as the commutator 5 crosses the brushes, are clear. There are two very close arcing events 16 due to the arcing on each brush occurring at slightly different times. Thus, as described in the Prior Art, if the number of segments on the commutator 5 is known the speed of the electric motor 1 can be calculated.

Alternatively, the ADC 9, high speed PCI card 10 and computer processor 11 can be employed to calculate the speed of the electric motor 1. Fast Fourier Transform (FFT) techniques are employed so as to convert the detected arcing events 16 so as to provide information regarding rotational speed. Figure 5 schematically presents the FFT carried out by the electric motor monitoring system 6 with the resultant speed representation depicted at 17.

Further processing techniques, carried out by the ADC 9, the high speed PCI card 10 and computer processor 11 provide estimates of the applied load or torque on the electric motor 1. It is found that a percentage of the detected arcing event signal, above a comparator level, is directly proportional to the applied load or torque. Therefore, by calculating the average width of the arcing event signal, over several thousand arcing events 16, provides a measure of the applied load or torque on the electric motor 1. The relationship between the width of the arcing event 16 and the applied load or torque is presented in Figure 6(a).

It is also found that there is an inverse proportional relationship between the RMS height of the arcing events 16 and the applied load or torque. Thus, the ADC 9, high speed PCI card 10 and computer processor 11 are employed to calculate RMS height so providing a means for potting the relationship with the applied load or torque, see Figure 6(b).

In addition to the relationships between the arcing events 16 and the applied load or torque it is found that the ratio of the width to height is sensitive to load or torque variations. Therefore, calculating the width to height ratio provides an ideal diagnostic for monitoring such variations in the applied load or torque.

The aforementioned techniques for calculating applied load or torque provide ideal means for testing the functionality of suppression of components such as interpoles or compoles (not shown) within the electric motor 1. A failure of one of these components would

alter both the height and the width of the arcing event 16 and so would show up on the graphs of Figure 6.

Both the condition of the brushes, commutators and flashover fault conditions, that can result in arcing extending between commutator segments of the electric motor 1, can be monitored using the same techniques. Changes due to degradation on the brushes ant the commutators will affect the height and frequency of the arcing event signal and so would again show up on the graphs of Figure 6.

Employment of the FFT techniques provides a further embodiment for measuring diagnostics of the electric motor 1 as outlined in Figure 7. Using the ADC 9 and the high speed PCI card 10 a frequency modulated data sample 18 can be obtained. FFT of this data sample 18 by the computer processor 11 provides a frequency spectrum 19 with side bands 20. These frequency side bands 20 are indicative of variations in the speed of the motor 1 produced by faults such as slipping belts, eccentric gearing etc.

The described embodiment of the electric motor monitoring system 6 also provides a means for evaluating possible mechanical eccentricity variations on the axis of rotation of the electric motor 1. This may be carried out both at the installation stage as well as during servicing of the motor 1 so allow the efficiency of the electric motor 1 to be optimised.

A similar technique is employed to monitor the amplitude modulation of the arcing events 16, as outlined in Figure

8. FFT of an amplitude modulated data sample 21 produces a frequency spectrum 22 with side bands 23 that are indicative of friction variations within the motor e.g. within the bearings, in the clutch mechanism, or due to imbalances in the load etc.

The aforementioned electric motor diagnostics have been described in isolation for clarity purposes. However, due to the nature of FFT it is possible to measure combinations of these diagnostics simultaneously as outlined in Figure 9. Employing appropriate software processing allows different faults known to occur within electric motors 1 to be distinguished e.g. broken brushes, wear in the commutator, excessive vibrations, eccentricity problems etc. Different frequency spectrum components and magnitudes of these components from the captured data sample may be appropriately filtered to isolate the fault condition.

A further embodiment of the electric motor monitoring system 6 employs a current measuring technique 24, as shown in Figure 10, for calibrating the electric motor monitoring system 6. Calibration employs the RF antenna torque measuring technique (T1) as described in Figure 6(a) and the measurement of the current I through the electric motor 1. By multiplying the measured current I by the torque constant K, that is an inherent property of the electric motor 1, an estimate for the applied torque (T2) is obtained. Ideally these two methods should provide the same value for the applied torque. Any difference between these values is indicative of contamination within the motor 1 thus, the offset (T2-T1)

can thereafter be added to the T1 torque value to compensate for any contamination.

The described electric motor monitoring system 6 is an ideal means for testing an electric motor 1 at the end of a manufacturing process. It provides for checking the functionality of the interpoles, decoupling capacitors and for identifying obvious manufacturing faults such as poor connectors.

The present invention offers several inherent advantages over the Prior Art. It can be employed to measure speed, acceleration and torque of the associated the electric motor 1. Employment of the balanced screened loop antenna 7 significantly improves the signal to noise ratio of the RF detected signals and so provides more accurate readings of these diagnostics.

A second advantage of the present invention is that the employment of FFT techniques provides a means for measuring and locating both electrical and mechanical faults within the electric motor 1.

A further advantage of the present invention is that it provides an electric motor monitoring system 6 that provides portable, adjustable and non-intrusive measurement of various diagnostics of the electric motor 1. Therefore, the electric motor monitoring system 6 does not require the electric motor 1 to be stopped for installation purposes. In addition, where it is required to monitor a large number of electric motors it is possible to employ the same system that can simply be

located and frequency matched, in turn, to each individual electric motor.

A yet further advantage of the electric motor monitoring system 6 is that when used in conjunction with standard torque measurement techniques it provides a means for self calibration and compensation to take account of contamination within the electric motor 1.

Further modifications or improvements may be incorporated without departing from the scope of the invention herein intended.

INFORMAL

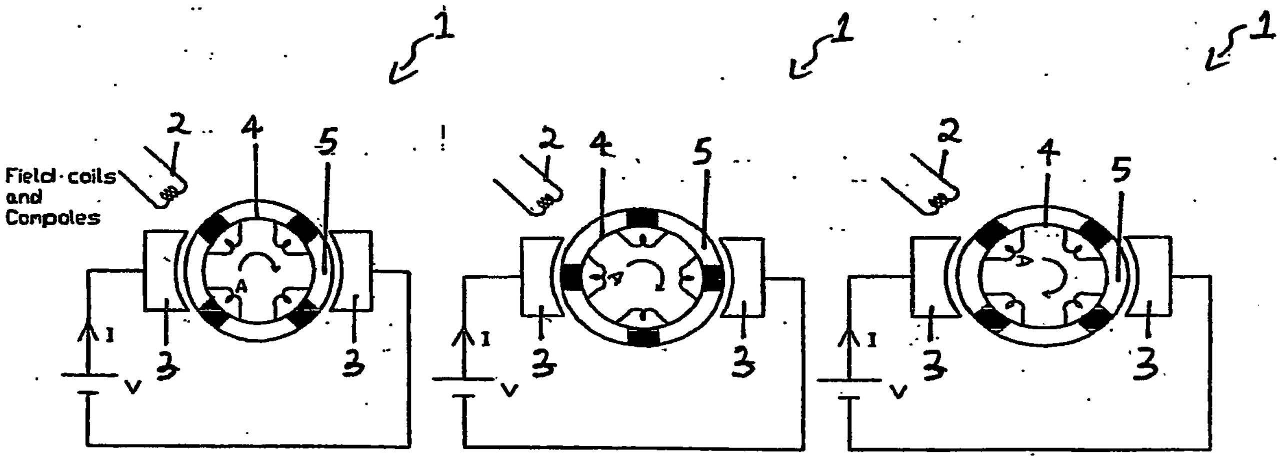


Figure 1(a) Figure 1(b) Figure 1(c)

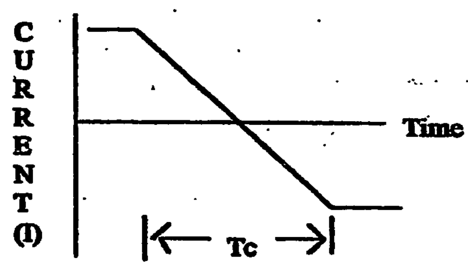


Figure 1(d)

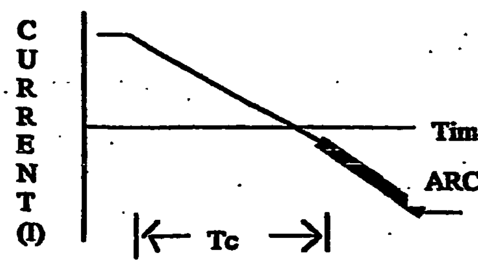


Figure 1(e)

INFORMAL

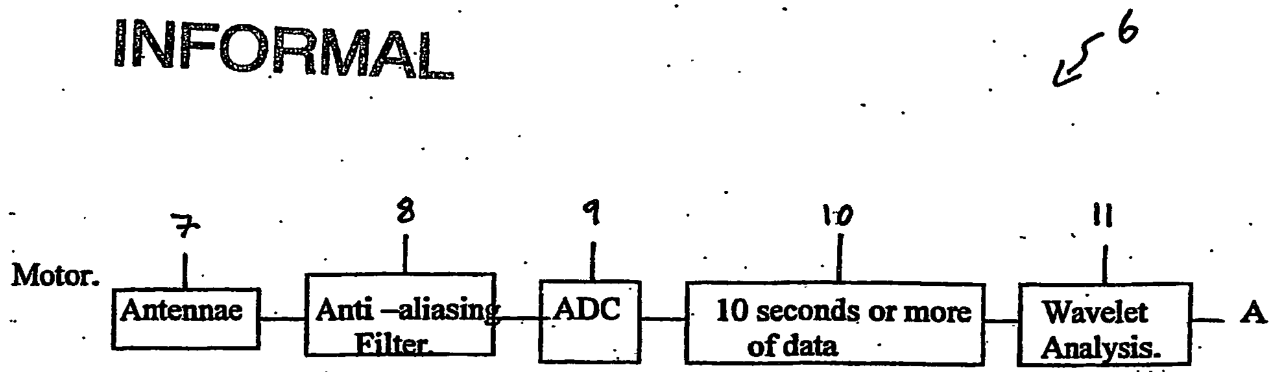


FIGURE 2

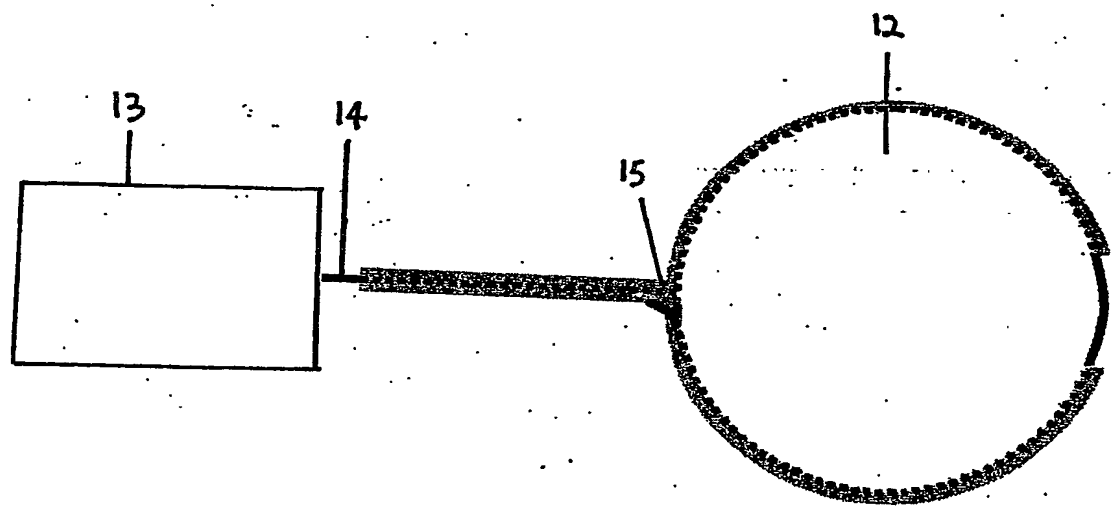
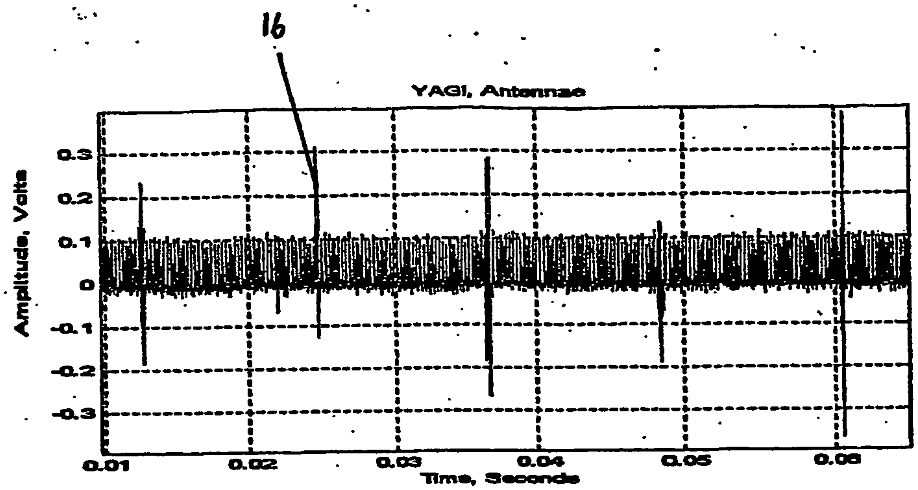
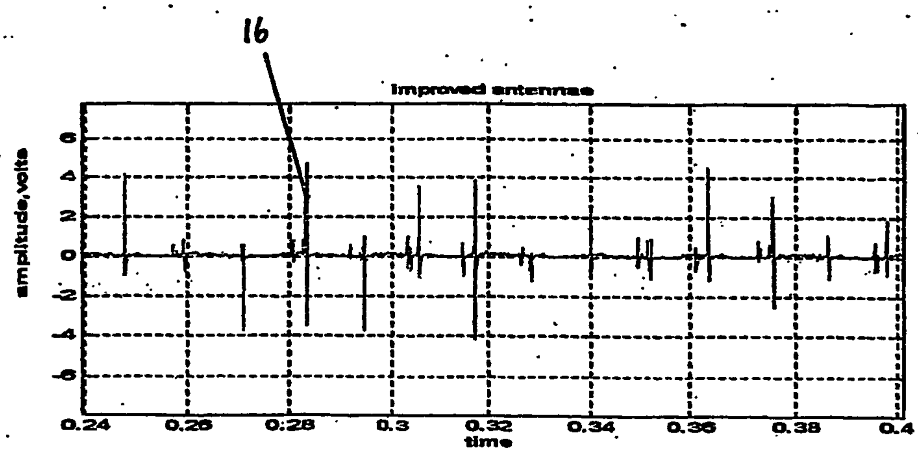


FIGURE 3

INFORMAL



(a)



(b)

FIGURE 4

INFORMAL

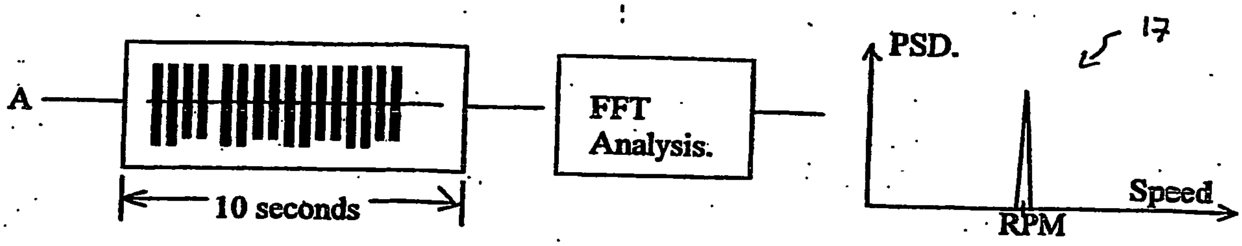


Figure 5

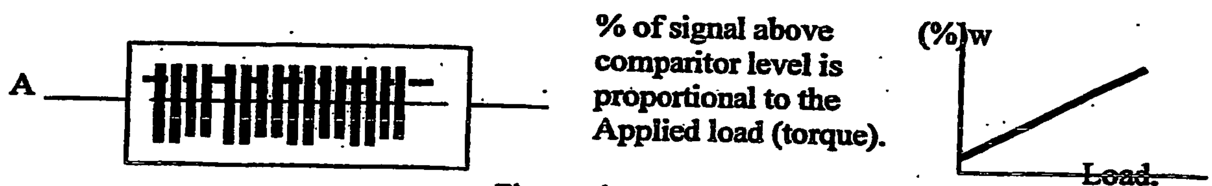


Figure 6(a)

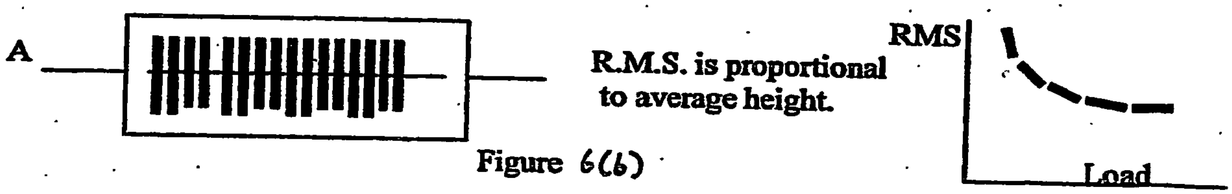


Figure 6(b)

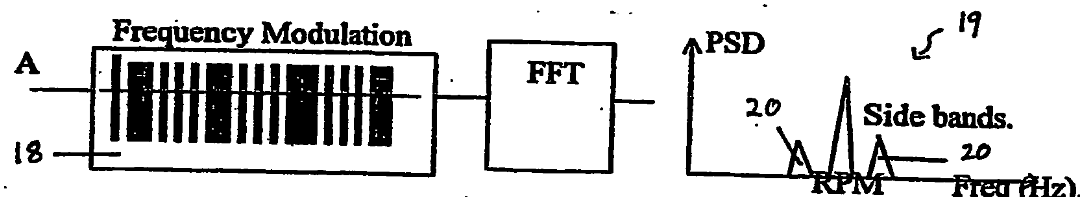


Figure 7

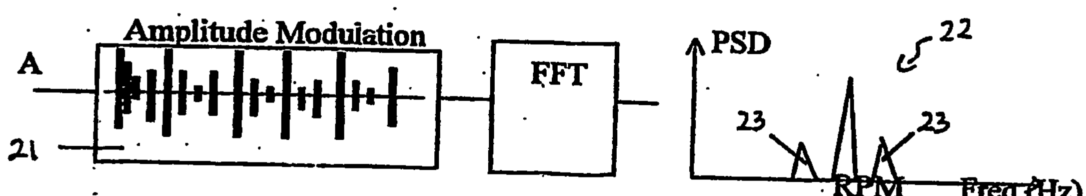


Figure 8

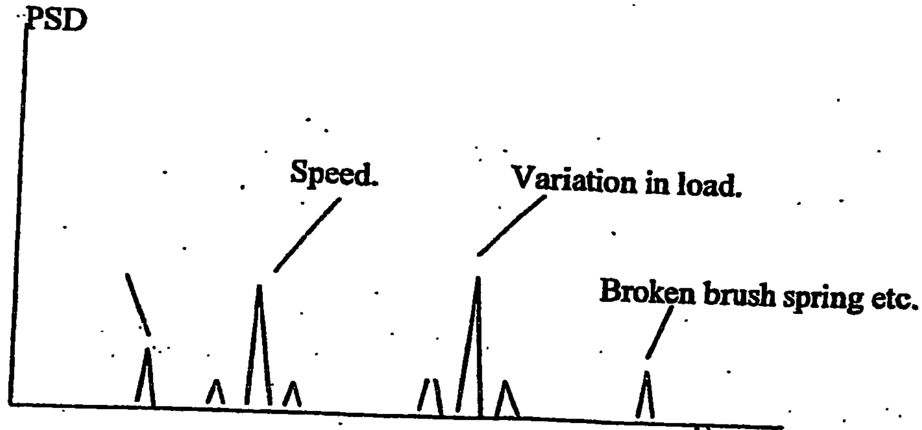


Figure 9

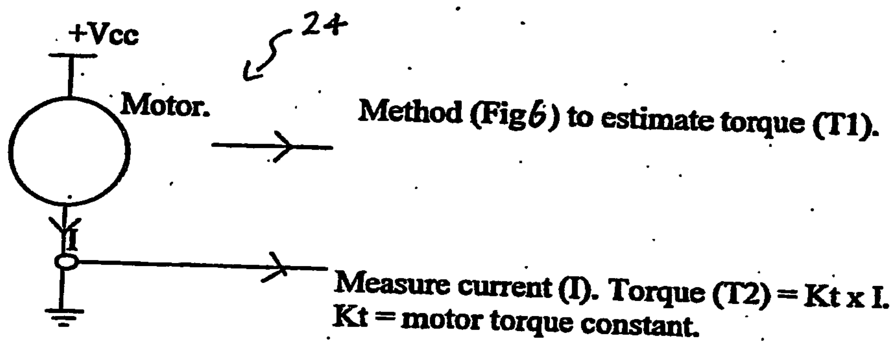


Figure 10

INFORMAL